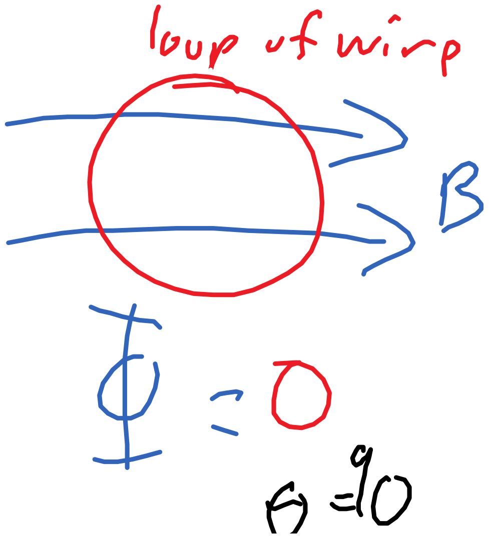
Electromagnetic Induction

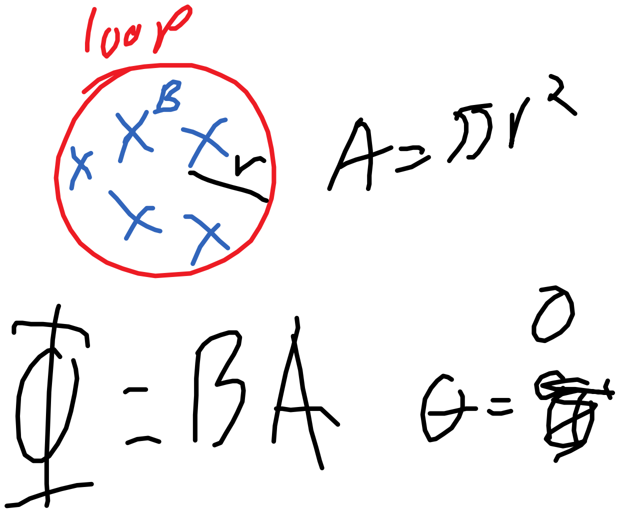
Recall: A current in a wire creates a magnetic field around the wire.
More generally, a changing electric field (ie moving charges) induces a magnetic field.

A change in the magnetic field induces an electric field.
Eg. If you move a magnet near a coil of wire, a current is induced in the wire.

Flux - Φ is the product of the magnetic field and the area crossed by the magnetic field.

$\Phi = BA \cos \theta$
Where θ is the angle between the magnetic field, B, and the vector perpendicular to area, A.





$$\text{Emf} = -N\frac{\Delta\Phi}{\Delta t}$$

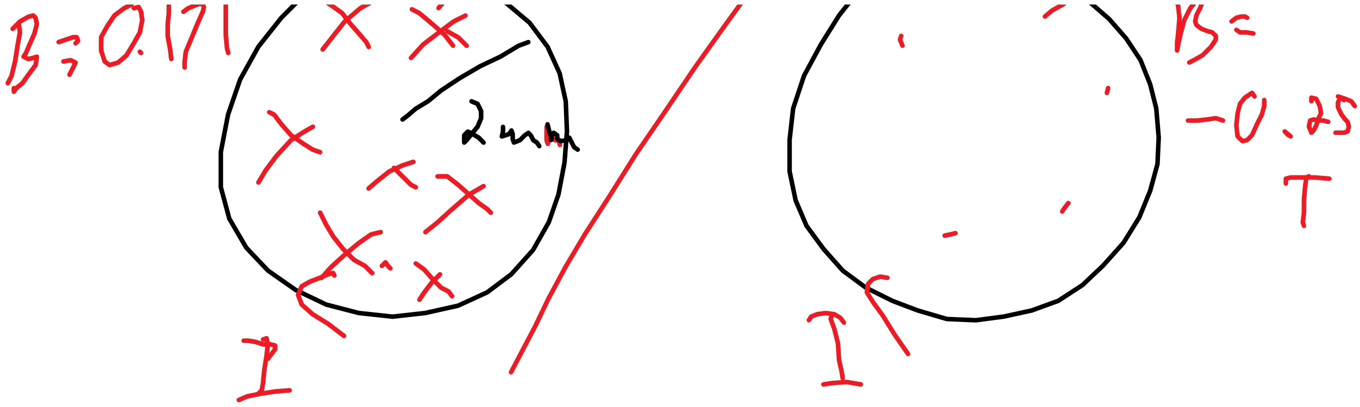
Opposes the change in flux

Emf is Voltage around the loop, V.

N is the number of loops.

t is time for the flux to change.

Eg. 50 circular loops of wire radius 2.0 mm are in a 0.17T magnetic field. If the field gradually changes to -0.25T over 0.20s what is the emf induced in the coils? What is the direction of the current?



Trick: the induced current creates a magnetic field opposing the change in flux.

You go from magnetic field into the page to no magnetic field. A magnetic field into the page opposes that change, therefore the current is clockwise by the right hand rule.

In the second diagram, the magnetic field changes from no magnetic field to a field out of the page. A magnetic field into the page opposes that change, therefore the current is induced clockwise.

$$Emf = -N\frac{\Delta \Phi}{\Delta t} = -\frac{N\Delta BA}{\Delta t} \quad (\Delta B = B_f - B_i)$$

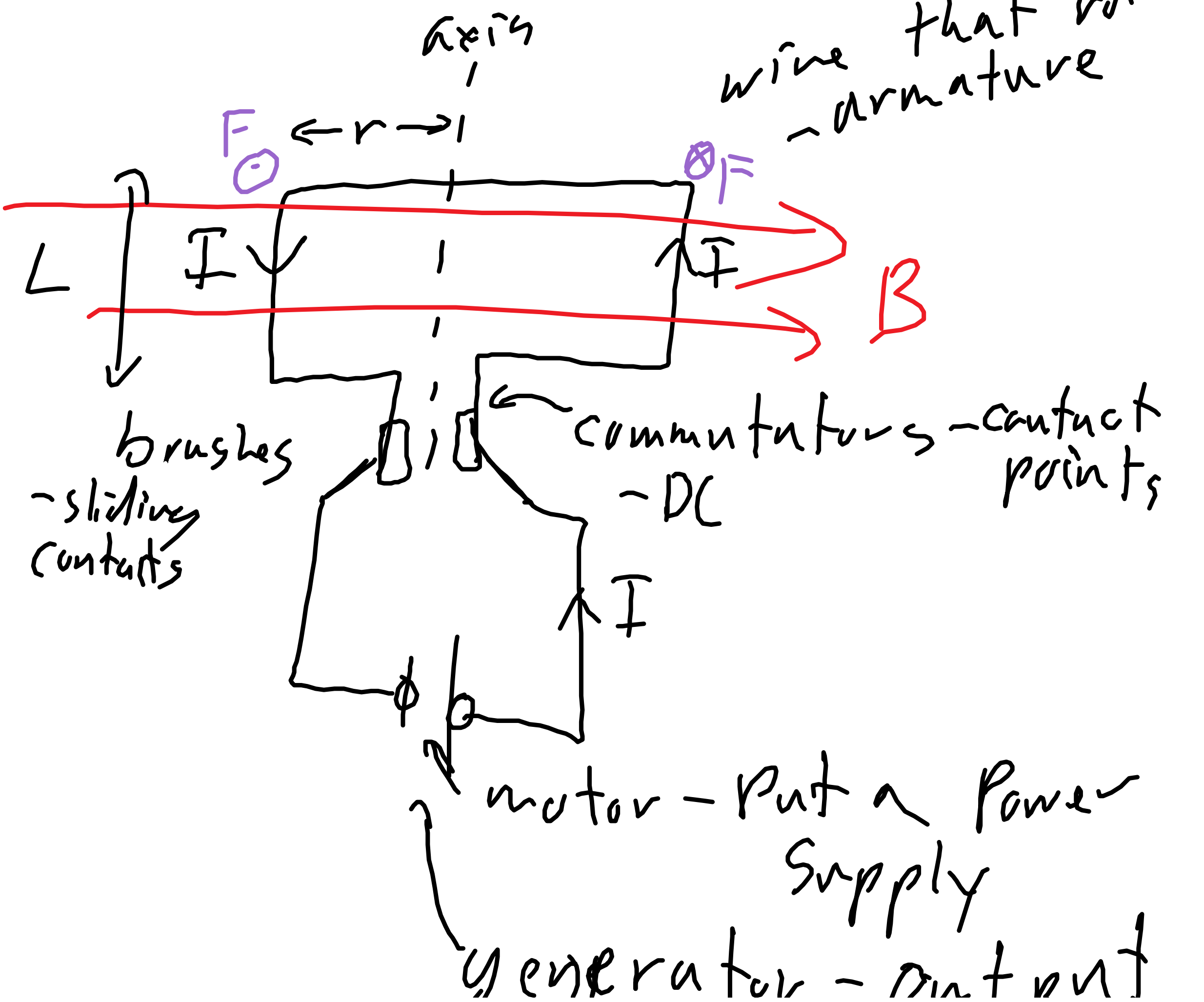
$$Emf = \frac{50 \times (-0.25T - 0.171T)\pi(2\times10^{-3}m)^2}{0.20s}$$

$$= 1.3\times10^{-3}\ V$$

We have a motor, coil of wire in a magnetic field that rotates when a current is run through it.
If the coil rotates without an external current, it is a generator producing current.

Data:
When connected to a 6.0V power supply, the motor spins at 3.5A of current at a constant rate.
When I hold the armature so it can't spin, the current jumps up to 8.0A.
What's the deal?

Generator / Motor



generator - output

The force on the wire = BIL causing the armature to rotate.
The rotation of the armature makes the motor act like a generator with an induced emf = -N $\Delta\Phi/\Delta t$

Keeners:

rotating at frequency f

$\Phi = BA\cos\theta = BA\cos 2\pi f t$

first derivitive - $2\pi f BA \sin 2\pi f t$

non-keeners - induced Emf $\propto$ f
Back

f = 0 Back Emf = 0

What is the a) armature resistance?
b) back Emf

of our demo, 6.0V, 8A no spin
3.5A with spin

a) $R = \frac{V}{I} = \frac{6.0V}{8.0A} = \underline{0.75\Omega}$

b) $V = Ir + \text{Back Emf}$

$6.0V = (3.5A)(0.75\Omega) + \text{Back Emf}$

$\boxed{\text{Back Emf} = 3.4V}$

c) If you load the motor so it rotates at half the frequency, $\text{Back Emf}_2 = \frac{1}{2}\,\text{Back Emf}_1$

$= \boxed{1.7V}$

pg 566 - 567 Kanecs

Problems; 2, 5, 10, 15, 19, 21

$P = I^2 R$

↑ bulb only

$I = \sqrt{\frac{15W}{11.3\Omega \text{ or } 15.3\Omega}}$ 1.15A or 0.99A

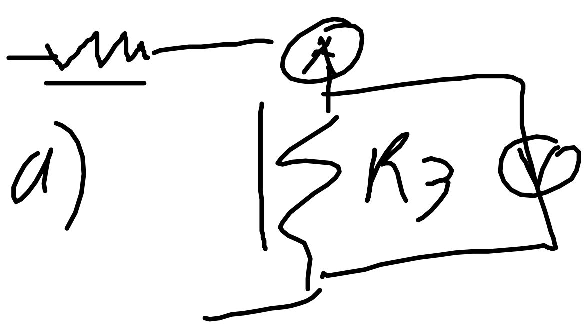
b) $Emf = IR + Ir$

$= I(11.3 \text{ or } 15.3 + 1.2\Omega)$

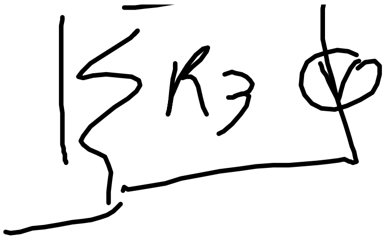
$= 16/15 V$

c) $Q = It = I \, 60s$ 69C or 66C

2 a)



$\frac{1}{\left(\frac{1}{R_2} + \frac{1}{R_3}\right)} + R_1$

2 a) 

$\left(\frac{1}{R_2}+\frac{1}{R_3}\right)+R_1$

b) $R_T = 42\,\Omega$

2.6 V, 0.86 V

$I = \frac{V}{42\,\Omega}$ $\quad V_? = V - IR_1$

$I_3 = \frac{V_3}{R_3} = 86\text{ mA}, 29\text{ mA}$

RHR

$\frac{1}{2}mv^2 = Vq$

D vs V_d

D vs $\frac{1}{V_a}$

D vs I

1.3×10^7 m/s or 1.6×10^7 m/s

c) $F = qvB$

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d) up RHR

e) 3.1×10^{-3} m or

$$r = \frac{mv^2}{F} = \frac{mv}{qB}$$

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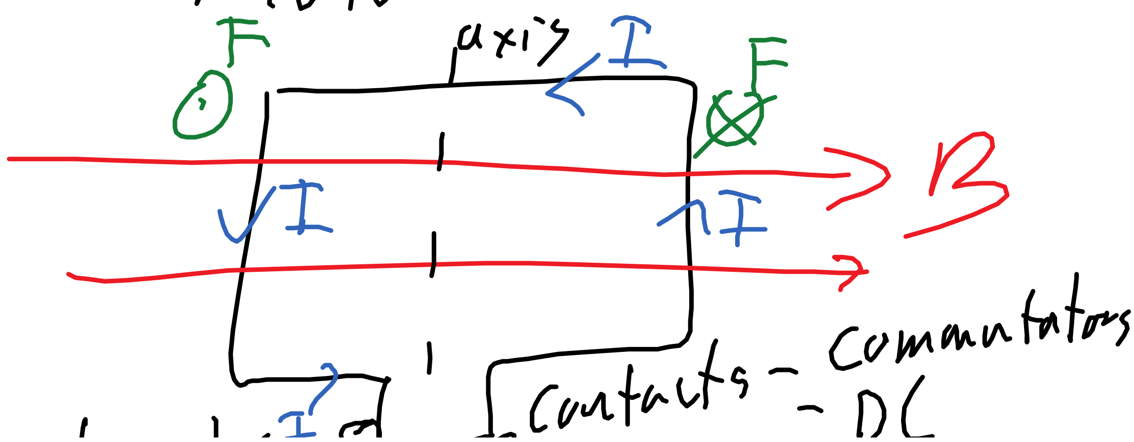
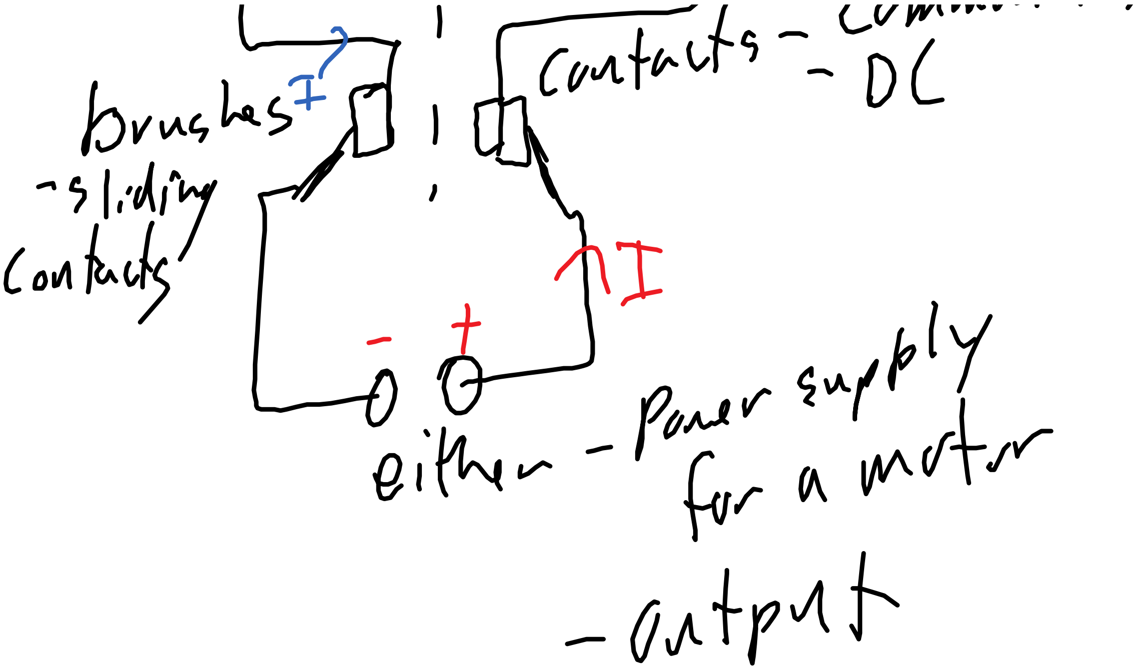
Motor or Generator





The rotating armature (coil of wire) induces a back emf - a voltage opposing the applied voltage - because it acts like a generator as it spins. When it doesn't spin, there is no back emf.

$$\text{Emf} = -N\frac{\Delta\Phi}{dt} = -N\frac{\Delta\, BA\cos\theta}{\Delta t}$$

$\omega \rightarrow 2\pi f t$

Keener's

$$\text{or } -NBA\,\frac{d\cos 2\pi f t}{dt}$$

$$2\pi f\,NBA\,\sin 2\pi f t$$

Peak $V = 2\pi f NBA$ for a generator or for Back Emf

Non-keeners Back Emf $\propto f$

Eg. A 6.0 V power supply runs a motor with a 3.5A Current at full revolution rate, f.
When the armature is held so it can't rotate, 8.0 A run through the armature.

a) What is the electrical resistance of the armature?
b) What is voltage in the armature at full revolution?
c) What is the back emf at full revolution?
d) If the motor has a load causing it to rotate at half f, what is the back emf?
e) Keeners - if the armature has 80 loops and an area of 1.0 cm^2 what is the magnetic field strength? Remember Vrms =1/root 2 Vpeak

1.15x60=69.0
1.2x60=72